



COMPUTATIONAL EM: RAJ AND THE GOLDEN YEARS

**Tom Cwik
Jet Propulsion Laboratory
Pasadena CA**

**EM Symposium in Honor of Raj Mittra
Urbana, IL
September 27, 2014**

In the Beginning ...



And where are we now? ...



And where are we now? ...



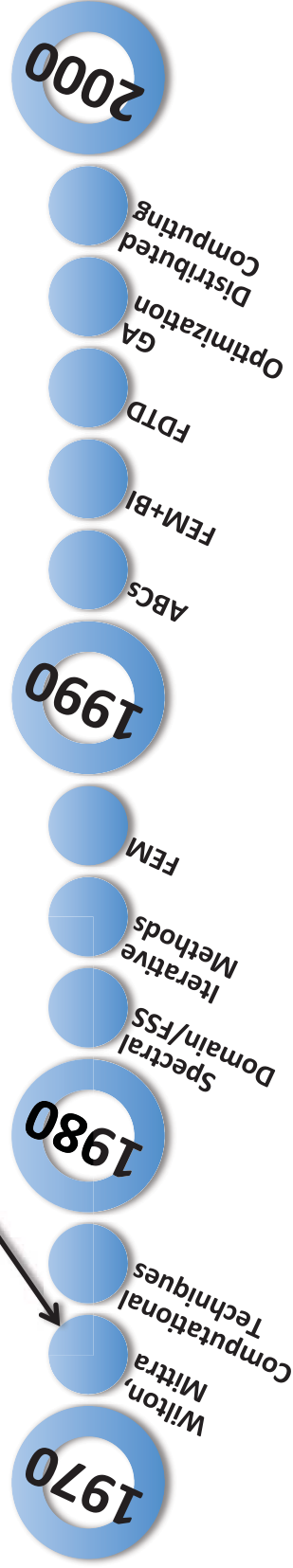
Timeline ...

310

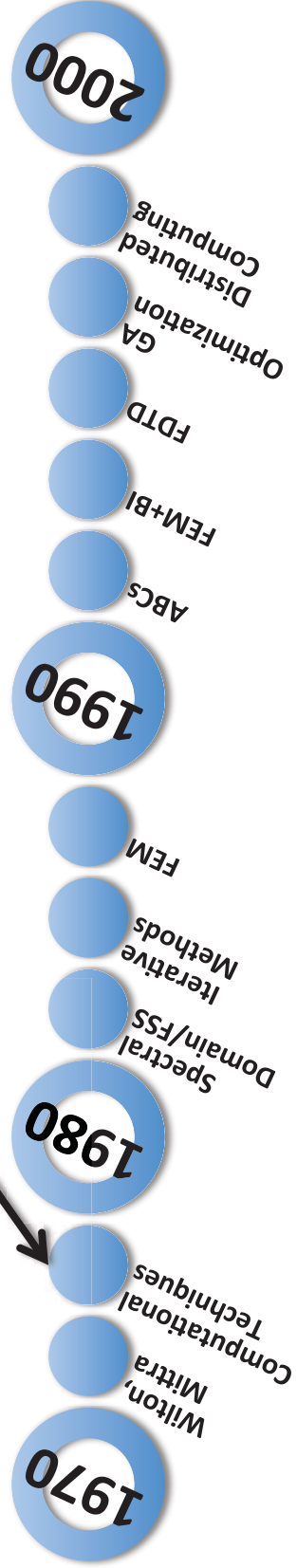
IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. AP-20, NO. 3, MAY 1972

A New Numerical Approach to the Calculation of Electromagnetic Scattering Properties of Two-Dimensional Bodies of Arbitrary Cross Section

DONALD R. WILTON AND RAJ MITTRA, FELLOW, IEEE



Timeline ...



Timeline ...

Distributed Computing

GA & Optimization

FDTD

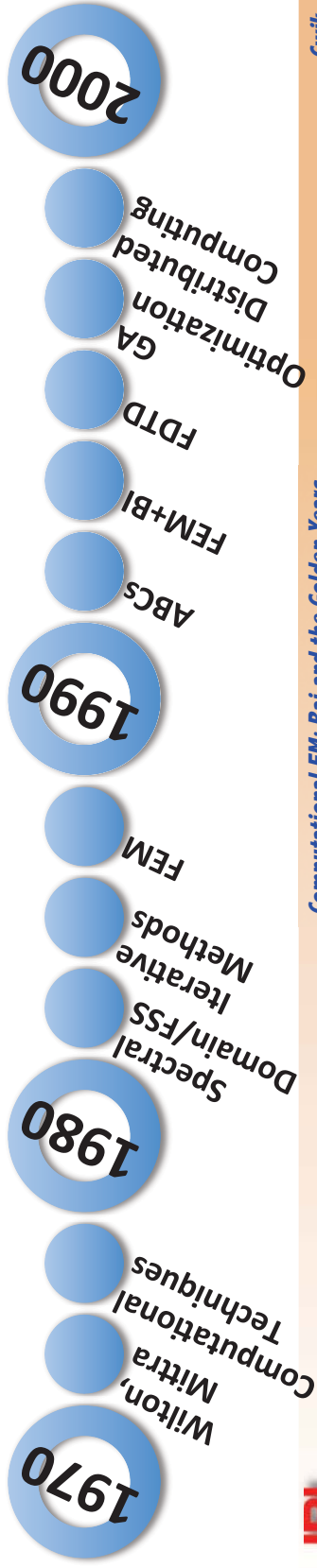
FE & Integral Equations

Absorbing BCs

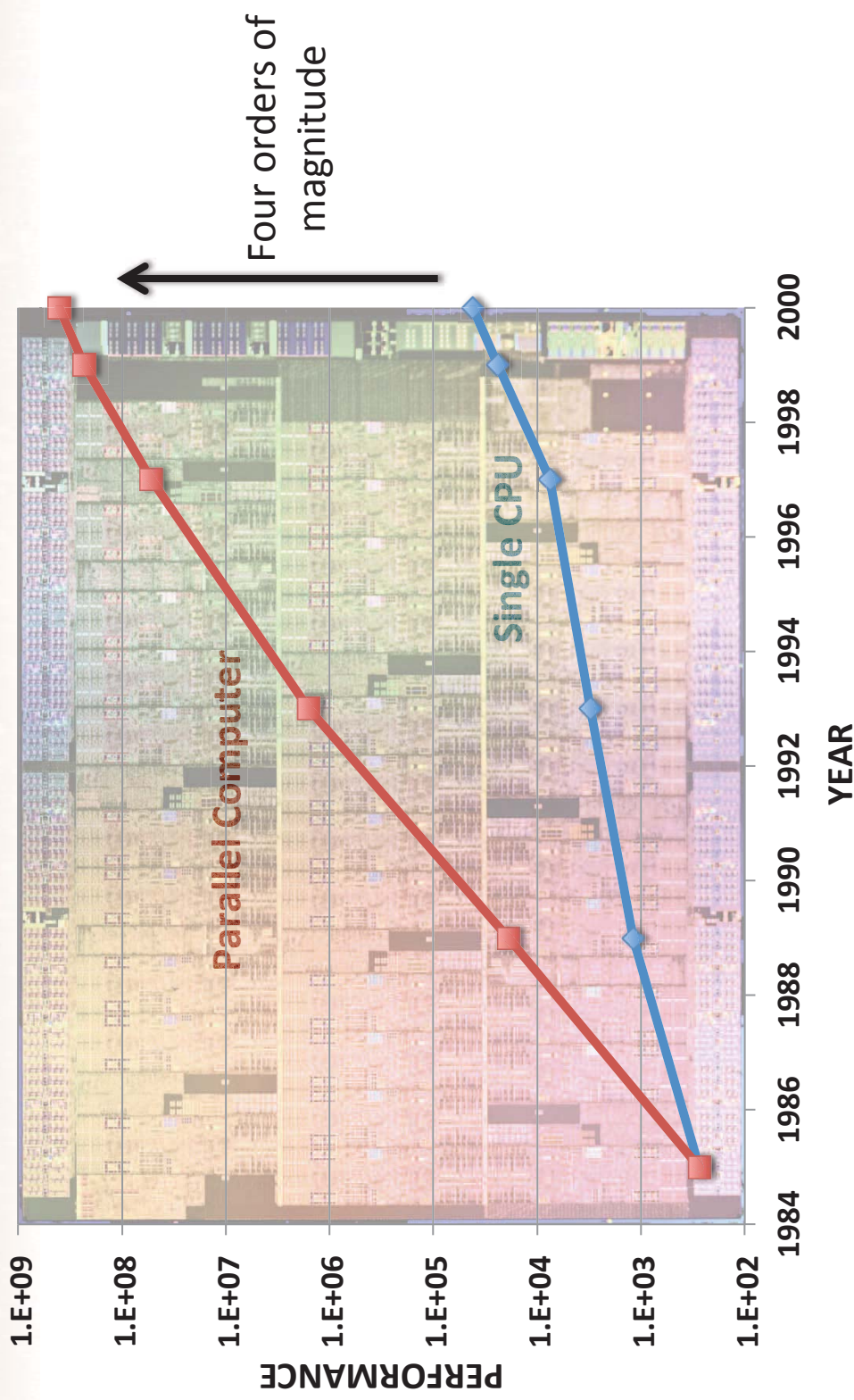
Finite Elements

Iterative Methods

Spectral Domain & FSS



Computational advance brings opportunity ...

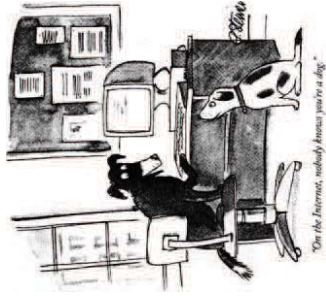


As does the internet ...

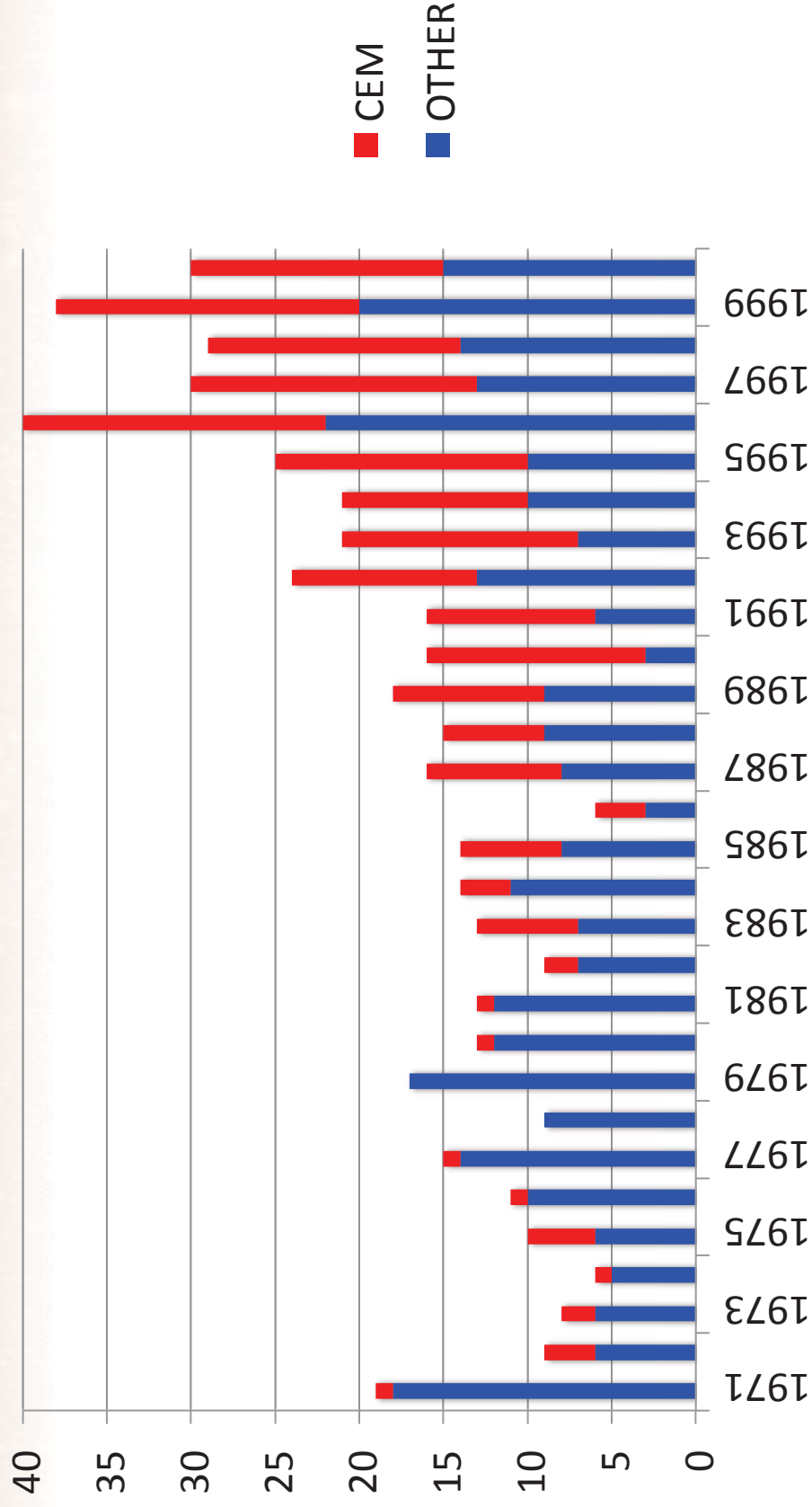


"On the Internet, nobody knows you're a dog."

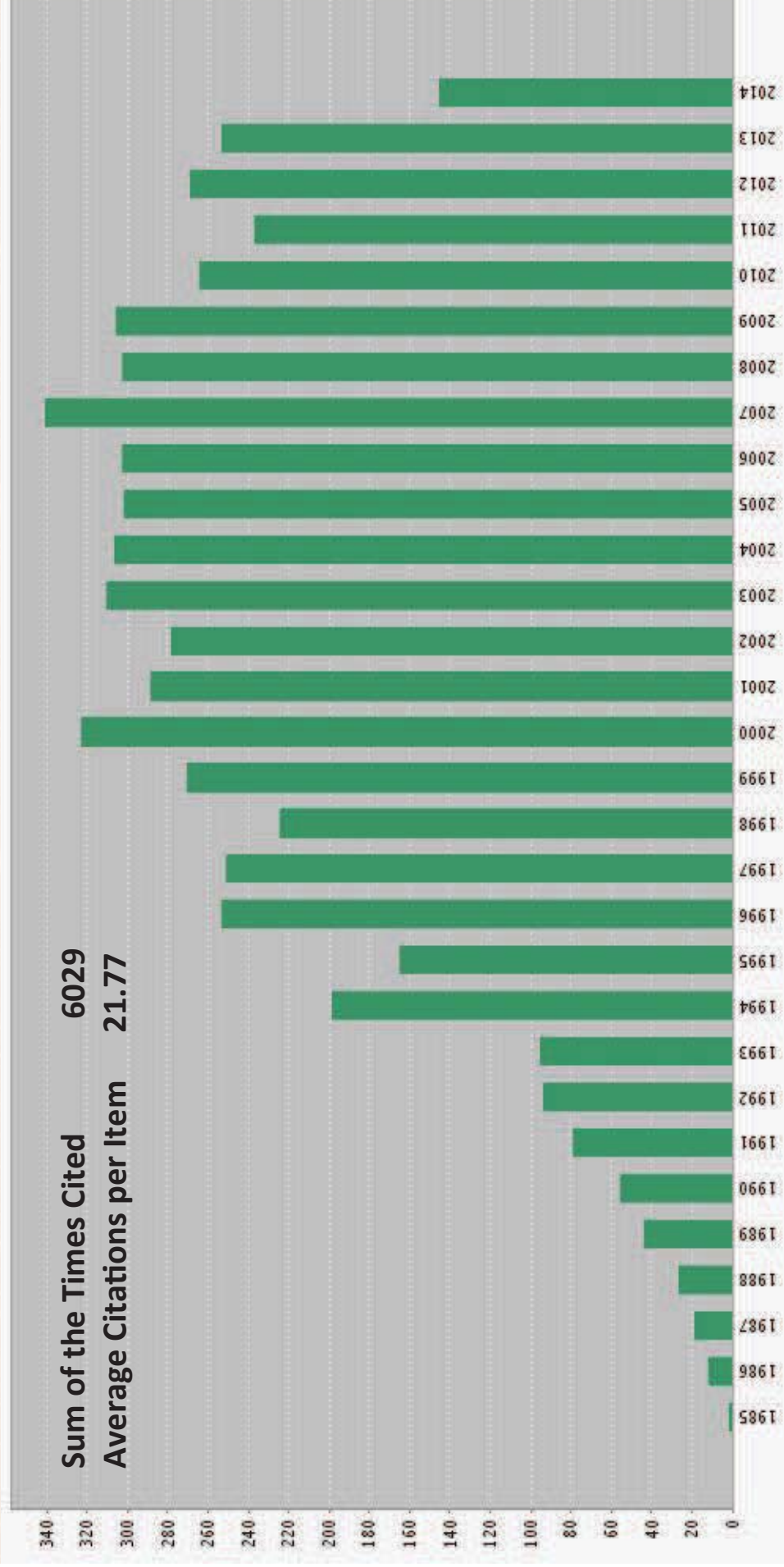
And software engineering ...



Raj's CEM publications



Raj's CEM citations 1985-2000



Method of the month club ...

Biconjugate Gradient

Conjugate Gradient

Spectral Iterative FFT

Conjugate Gradient Squared

Spectral Iterative

Spectral-Iterative

FEM-MOM

Conjugate-Gradient-FFT

FEM

FEM-BOR

FDTD

ABC

Bayliss-Turkel

Non-orthogonal FDTD

Wilcox ABC

NABC

Conformal FDTD

PML

Method of the month club ...

I JUST WANT TO GRADUATE!!!

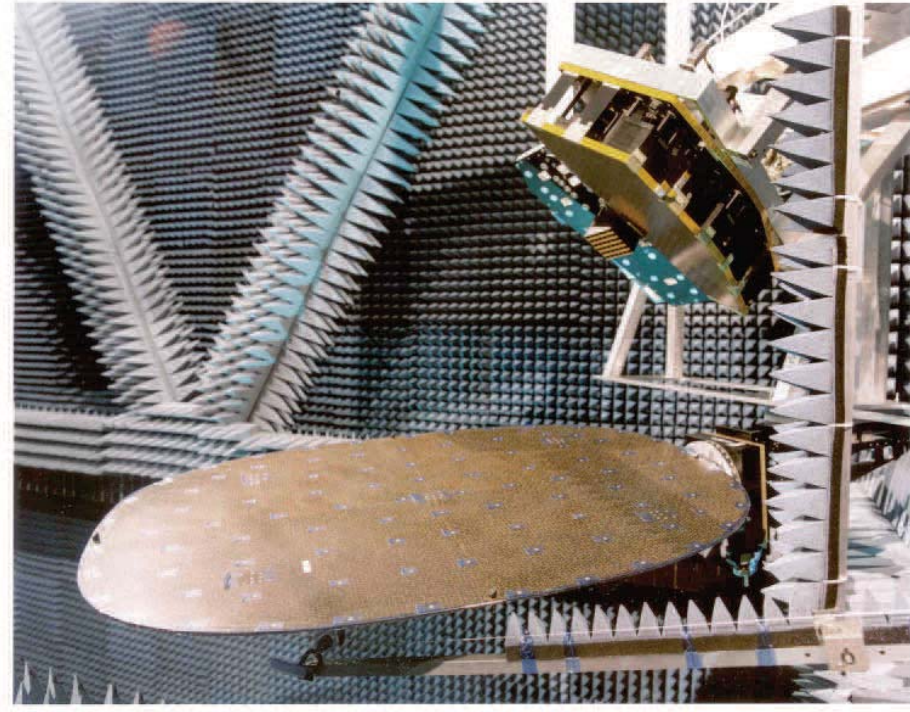
Results: Stealth ...



www.nationalmuseum.af.mil



Results: Stealth, FSS and Large Antennas

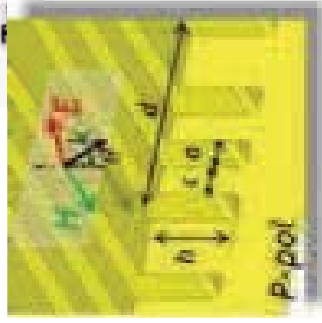
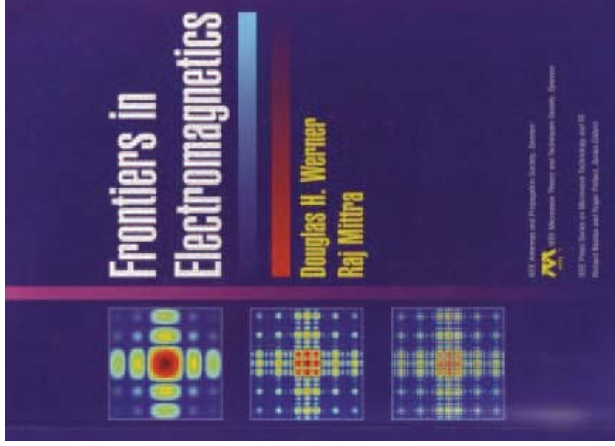
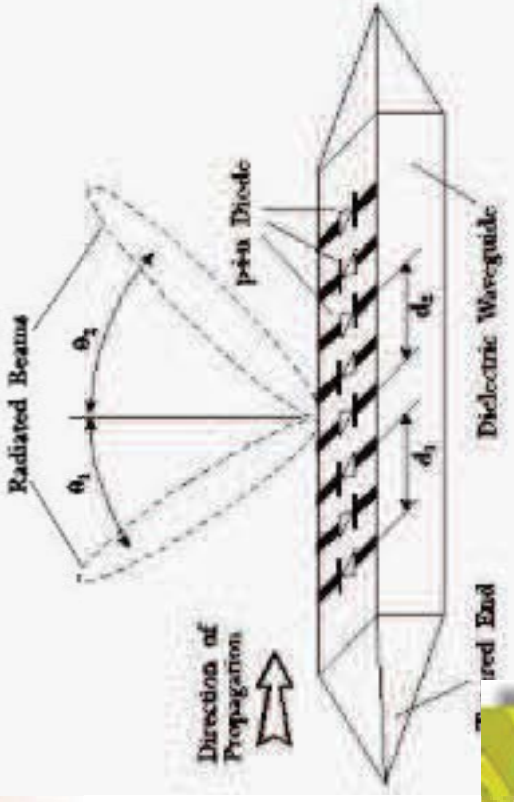
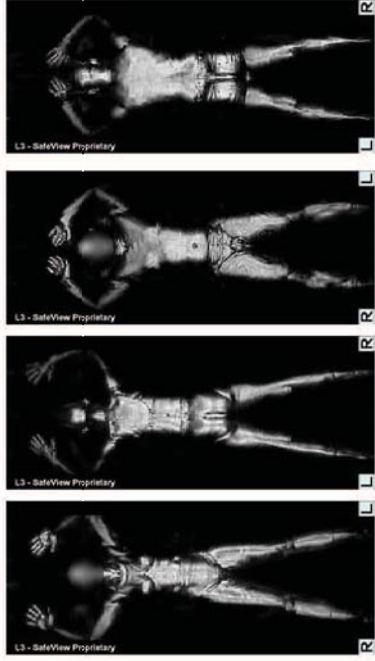


Modern Antenna Handbook, Balanis Ed.



www.defenseindustrydaily.com

Results: MMIC components and high speed circuits



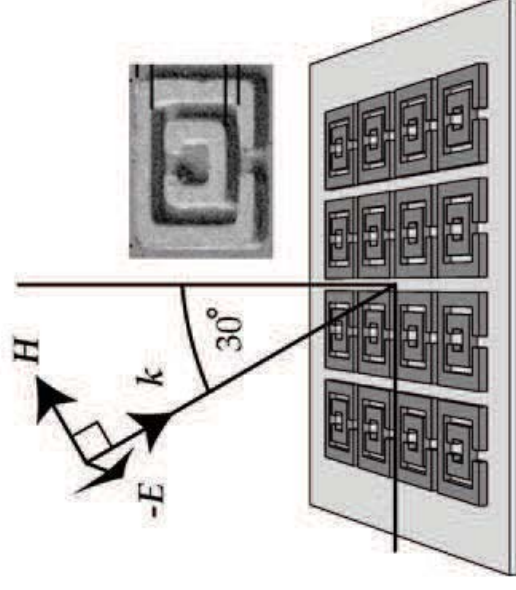
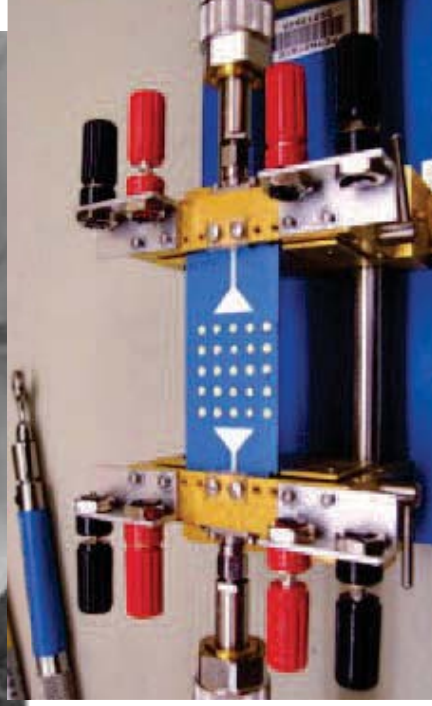
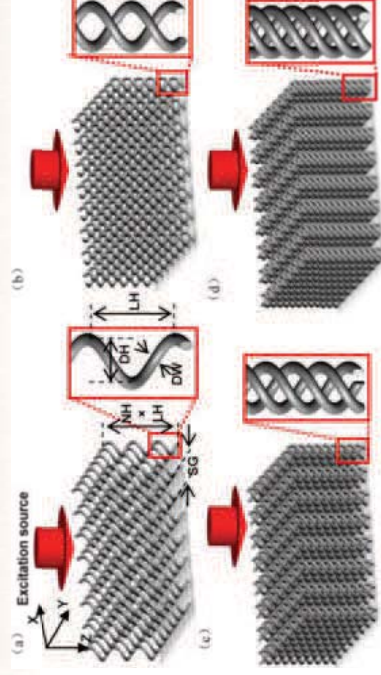
96

IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. 36, NO. 1, JANUARY 1988

Analysis of MMIC Structures Using an Efficient Iterative Approach

CHI HOU CHAN, MEMBER, IEEE, AND RAJ MITTRA, FELLOW, IEEE

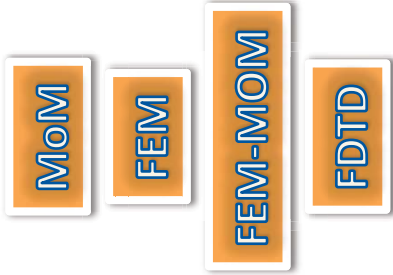
Results: Integrated antennas and meta-materials



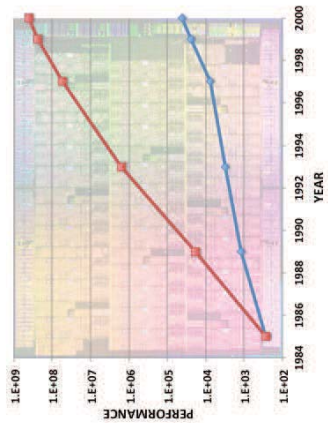
Foundations ...



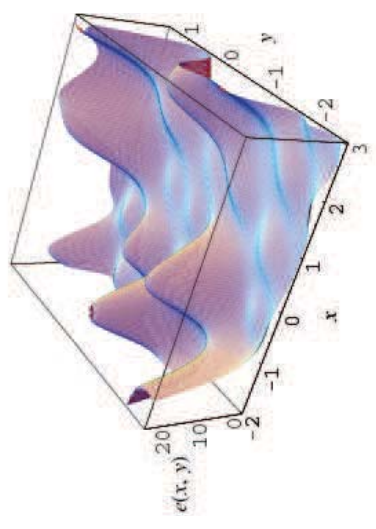
Analytical



Algorithmic



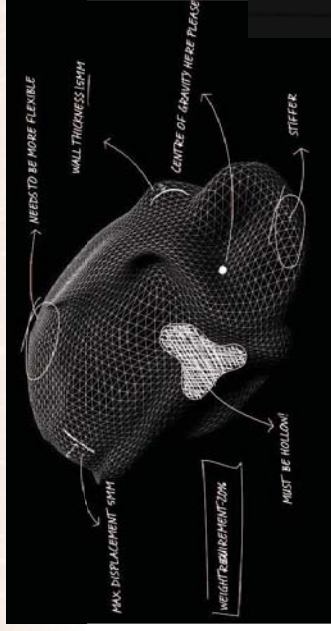
Computational



Optimization

A future: design integration

Requirements – Analysis & Optimization – Additive Manufacturing



Images courtesy of Autodesk and Within

The most important result ...

